The Influence of Defects on the Mechanical Properties of some Polyurethane Materials

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Necuron is a polyurethane material (PUR) that is used for various applications of industry. The use of these materials in industry increased in recent years because of their good mechanical and machinability properties. Good knowledge of the mechanical behaviour of these materials is highly important therefore this work presents the results of tensile tests carried out on four different types of Necuron. The twenty-eight specimens used were divided in two categories: one without defects and one with defects of two types. Results show that Necuron 1020 is the stiffest material, whereas Necuron 1300 is the strongest.

Keywords: tensile testing, necuron, tensile strength, Young's modulus

Polyurethane (PUR) materials are usually characterized by high compression strength, good machining, high stiffness, wear resistance and low absorption of humidity. These characteristics assure a good dimensional stability [1] and make PUR materials suitable for a wide range of industrial applications such as: insulators, rollers, housing parts, clock gearing, plain bearings, gearwheels, molding tools, different fixtures, seals and others (fig. 1) [2].

Fig. 1 Gearwheels made from Necuron

As the applications are numerous, good knowledge of the mechanical characteristics of these materials is quite important, especially because many data sheets of manufacturers lack reliable information regarding material properties and they usually differ from one producer to another. It can be found, for example, that in the description of some polyurethane materials, necuron included, the impact strength refers to notched specimens and for some to un-notched specimens. This and the fact that polyurethane materials have different chemical composition and are produced in different conditions shows how important are studies that can provide new characterization information and determine mechanical properties in different experimental conditions [3, 4].

Necuron is a PUR material, from the polymeric material family, usually used for application like: fixtures and gauges, master and copy models, models with high mechanical stress and tooling jigs, tools for serial production [5]. Lately Necuron was used in different research applications such as airplane wing tesing in wind tunnels or in bioengineering research for heart valve damage [6, 7].

In the last 10 years researchers have expressed an ongoing interest regarding the mechanical behaviour of different types of polymeric materials through some important studies that use different type of polymeric materials in various loading conditions, like tensile tests of different polymers [8, 9], assemblies of polymers, and tensile, compression and bending tests of polyurethane foams [10].

The aim of this study was to perform tensile tests on flawless and intentionally flawed specimens in order to characterize four types of Necuron: Necuron 840, Necuron 1001, Necuron 1020, and Necuron 1300.

Experimental part

Materials and testing methodology

All tensile tests were carried out using an MTS 810, 500 kN testing machine, equipped with Instron hydraulic grips (grip capacity 300 kN) (fig. 2).

Fig. 2 Instron MTS 810

A number of 28 specimens were tested using a traction experimental program. Geometry and dimensions of the specimens are shown in table 1 and figure 3. All tests were performed according to European Standards EN ISO 527-4 [11].

The loading speed was set to 2 mm/min. All tests were performed at room temperature (T=29^{0}C).

In order to investigate the influence of defects on each Necuron type, some of the specimens were left flawless

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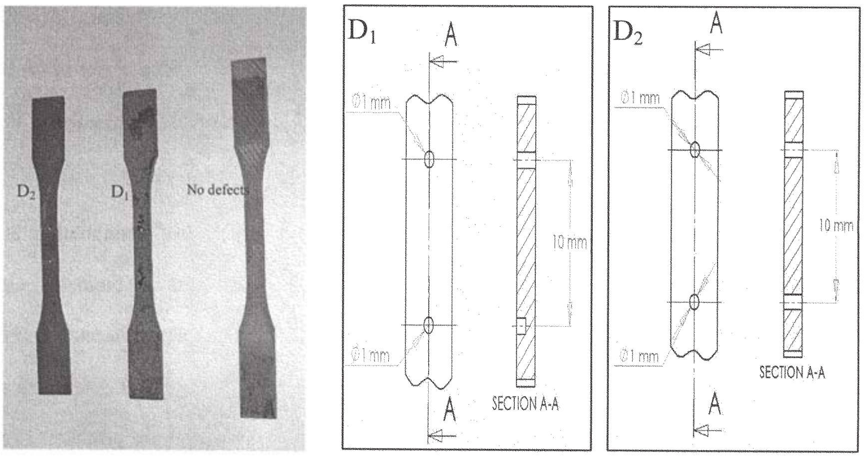

Fig. 3 Specimens for tests with and without defects

Table 1
DIMENSIONS OF SPECIMENS FOR EACH TYPE OF NECURON

No.	Type of NECURON	Width [mm]	Thickness [mm]	Length [mm]	Defects
1	1020	5.26	2.24	56	-
2		5.09	2.24	58	-
3		5.00	2.17	58	-
4		5.00	2.25	55	-
5		5.23	2.00	54	-
6		5.35	2.27	55	-
7		4.65	2.23	56	-
8		4.76	2.11	60	-
9		4.93	2.11	54	D_1
10		4.76	2.05	53	D_1
11		4.93	2.16	54	D_1
12		4.79	2.16	53	D_2
13		4.79	2.19	58	D_2
14		4.81	2.21	58	D_2
15		4.75	2.09	58	D_2
16	840	5.19	2.14	53	-
17		5.19	2.06	55	-
18		5.13	2.14	53	D_1
19		5.17	2.13	53	D_2
20	1001	5.15	2.15	52	-
21		5.18	2.17	52	-
22		5.17	2.16	53	D_1
23		5.21	2.20	52	D_2
24		5.21	2.20	54	D_2
25	1300	5.23	2.15	50	-
26		5.16	2.14	57	-
27		5.21	1.83	53	D_1
28		5.16	2.22	53	D_2

while others were realized with two types of defects (fig. 3). Specifically the first type consisted of 1 through hole (1 mm diameter) and 1 partial hole of 1 mm diameter, placed axially D_1 (table 1); whereas the second type consisted of two through holes (1 mm in diameter) placed also axially D_2 (table 1).

From the recorded data (in terms of load and deformation) stress-strain curves were obtained (figs. 5-8) and the mechanical characteristics (i.e. Young's modulus and ultimate tensile strength) were determined.

The tensile strength or failure stress of the specimen was calculated according to European Standards EN ISO 527-4 [11] with the formula:

$$\sigma_f = \frac{F_{\max}}{A_0}, \quad [MPa] \tag{1}$$

where:

F_{max} is the maximum measured force in [N];

A_0 the initial cross-sectional area of the specimen in [mm^2].

The Young's modulus was calculated based on the following formula:

$$E = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1}, \quad [MPa] \tag{2}$$

where:

σ_1 [MPa] is the stress measured at the strain ε_1=0.0005;

σ_2 [MPa] the stress measured at the strain ε_2=0.0025 according to EN ISO 527-4 [10].

The density of each type of Necuron was calculated using the formula:

$$\rho = \frac{m}{V}, \quad [g/cm^3] \tag{3}$$

where m is the mass in [g] and V the volume in [cm^3]. In order to achieve these four Necuron cubes were used with the characteristics presented in table 2. The values obtained for density are also shown in table 2.

Results and discussions

The obtained values for the Young modulus, ultimate tensile strength and ultimate elongation for the different types of Necuron, with and without flaws, are presented in table 3.

Table 3 shows clearly that the presence of defects in the material affects the mechanical properties. Specifically, the specimens with two through holes (D_2) have the lowest values.

Figures 5 to 8 show the stress-strain curves for each Necuron types showing the normal curve as well as the curve corresponding to the defected materials (D_1 and D_2).

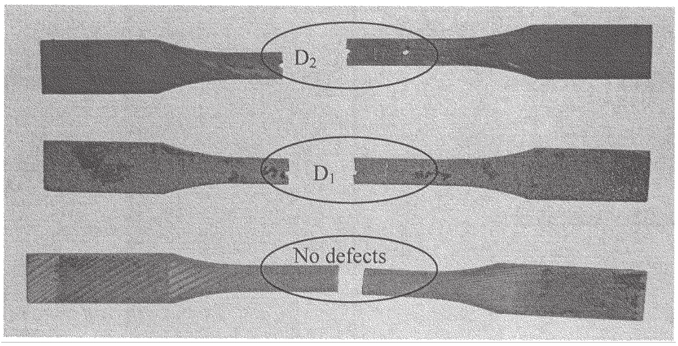

Fig. 4 Broken specimens

Table 2
VALUES OF DENSITY OF TYPES OF NECURON

Type of material	Density given by the manufacturer [g/cm^3]	Necuron cube characteristics		Calculated density [g/cm^3]
		Volume [cm^3]	Mass [g]	
Necuron 840	0.980	11,383	11,531	1.013
Necuron 1001	1.200	11,330	13,914	1.228
Necuron 1020	1.200	10,873	13.124	1.207
Necuron 1300	1.150	10,836	13.003	1.200

Table 3
VALUES OF MECHANICAL PROPERTIES FOR THE FOUR TYPES OF NECURON

Type of material	Mechanical property	No defects	D_1	D_2
Necuron 840	Young's modulus [MPa]	2250	2245	2111
	Ultimate tensile strength [MPa]	29.31	22.04	21.31
	Ultimate elongation [%]	2.40	1.34	1.31
Necuron 1001	Young's modulus [MPa]	2467	2491	2426
	Ultimate tensile strength [MPa]	23.61	21.45	20.51
	Ultimate elongation [%]	2.60	1.63	1.52
Necuron 1020	Young's modulus [MPa]	2922	2831	2619
	Ultimate tensile strength [MPa]	34.78	28.11	25.36
	Ultimate elongation [%]	2.50	1.28	1.34
Necuron 1300	Young's modulus [MPa]	2317	2216	2202
	Ultimate tensile strength [MPa]	39.36	34.60	34.02
	Ultimate elongation [%]	6.60	2.65	2.10

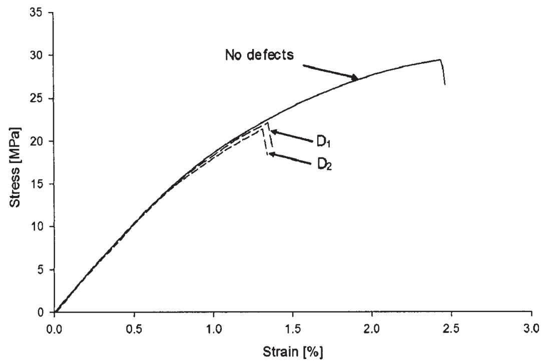

Fig. 5. Stress-Strain curve of Necuron 840 with and without defects

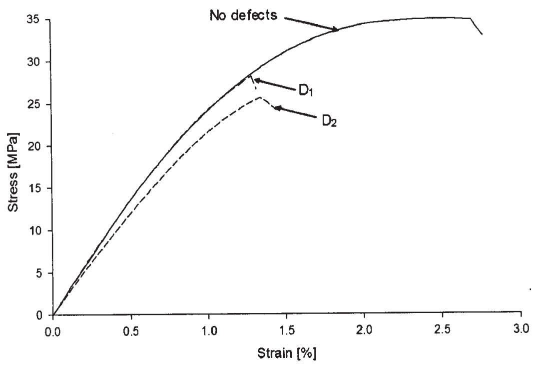

Fig. 7. Stress-Strain curve of Necuron 1020 with and without defects

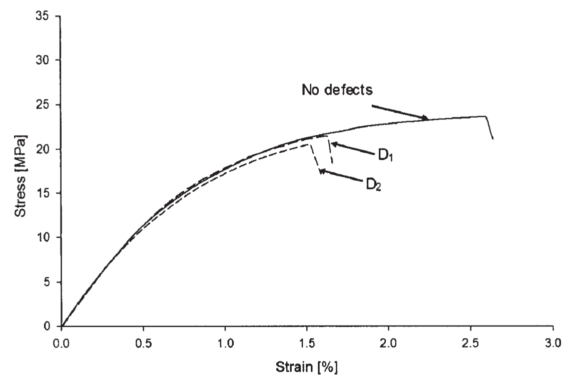

Fig. 6. Characteristic curve of Necuron 1001 with and without defects

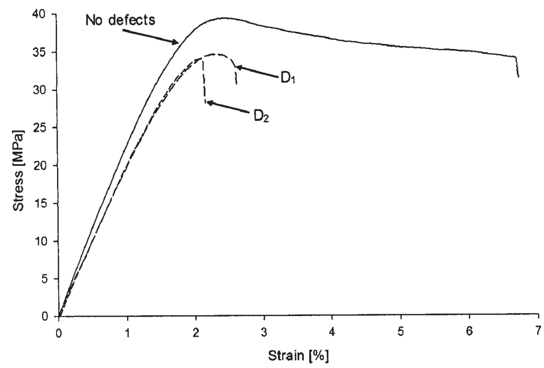

Fig. 8. Stress-Strain curve of Necuron 1300 with and without defects

Results (fig. 5-8) state clearly that the presence of defects in the material decreases the mechanical properties.

One can observe that Necuron 1020 is the stiffest of the four types of Necuron and Necuron 1300 is the strongest (figs. 5-8, table 3). Also, on the elastic segment of the characteristic curves one can observe that the decrease of Young modulus between the normal and flawed material is insignificant.

Conclusions

After undergoing the proposed experimental program, it was shown that out of the four types of Necuron, Necuron 1020 has the highest value for Young modulus and is the stiffest material, and Necuron 1300 is the strongest having the highest value for the ultimate tensile strength.

As Necuron is being increasingly used in different areas of the manufacturing industry, knowing the properties of these materials in different conditions is of great importance and relevance. There is still a big need for experimental programs using different testing techniques and a bigger number of specimens in order to obtain statistical reliable values regarding the mechanical properties of Necuron.

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